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EPHRAIM PORTER FELT State Entomologist

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Bulletin 57

ENTOMOLOGY 15

ELM LEAF BEETLE

IN

NEW YORK STATE

Edition 2

BY

EPHRAIM PORTER FELT D.Sc.

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Bulletin 57

ENTOMOLOGY 15

ELM LEAF BEETLE

IN

NEW YORK STATE

PREFACE

This bulletin appeared in June 1898 and as the first edition is practically exhausted, a revision embodying the more essential facts observed since then has been prepared in order to meet the demand for information concerning this deadly enemy of our elms, which is still extending its range in this state. This beetle has abundantly demonstrated its injurious powers in the vicinity of Albany, and in turn the feasibility of controlling it at a very reasonable expense has been proved.

The life history and habits of this beetle have been given somewhat in detail because unless they are thoroughly understood it is very easy to adopt means that are futile or only partially successful. In order to give the bulletin a more practical value, short accounts have also been included of three other insects, which, working with the elm leaf beetle, have aided greatly in ruining many noble elms.

In the portion devoted to remedies prominence has been given to the cost of spraying per tree, the proper apparatus and the time and manner of application. It is surprising to see what mistakes some make in dealing with insects and how methods of no value are clung to. To offset this tendency, two of the more common fallacies are mentioned and their futility shown.

E. P. FELT

Albany N. Y. January 1902

ELM LEAF BEETLE IN NEW YORK STATE

Galerucella luteola Müller

Ord. Coleoptera: Fam. Chrysomelidae

This insect has committed such extensive injuries to elms in cities and villages along the Hudson that it may be regarded as the most important natural enemy of shade trees in this state. Its depredations in this section probably outrank those of all other natural agents combined. Residents of places where this pest has established itself have repeatedly observed the grubs working on their elms and in many instances have seen two, or even three, crops of leaves destroyed in a single season without taking steps for the protection of their trees.

The causes for this condition of affairs are not hard to find, as the majority, if they notice the work of this pest at all, are inclined to trust in Providence and hope that its ravages will not be as severe the next season. Others see the grubs at work on the under side of the leaves or crawling about the tree but not being quite sure of the best method of controlling them, and as any method takes considerable labor, usually make no effort to subdue the pest.

Bad reputation of its family. This beetle is a member of the large, leaf eating family of Chrysomelidae, which comprises a number of our most injurious insects. It includes such well known pests as the asparagus beetle, Crioceris asparagi Linn., the Colorado potato beetle, Doryphora 10-lineata Say, the 12 spotted Diabrotica, D. 12-punctata Oliv. and the striped cucumber beetle, Diabrotica vittata Fabr., all well known insects against which the farmer must wage a more or less perpetual warfare. Another member of this family, the cottonwood leaf beetle, Lina scripta Fabr., recently inflicted serious damage on the large basket industry in the willow growing districts about Syracuse, Rochester and other localities in that part of the state. Judging from the well known records of its allies, we may expect that the elm leaf beetle will continue to be very destructive.

Recent injuries about Albany. The elm leaf beetle was recognized in Albany by the late Dr Lintner about 1892, having

probably made its way here a year or two earlier. Its ravages became more and more serious from that time till 1897, when most of the European elms along our streets were completely defoliated in early summer. The second growth of foliage was seriously injured the same year and some trees had their third set of leaves attacked. It was estimated in 1898 that fully 1000 elms had been killed within the city limits by this pernicious insect and many more would have suffered a similar fate, had it not been for the systematic spraying undertaken then and since continued. See pl. 3 and 4 for representations of the injury caused by this pest.

The record of this insect in Troy has been even worse than in Albany. It probably made its way to that city about the same time that it came here, and up to 1898 practically no effort had been made to check its ravages. At that time probably 1500 elms had been killed within the corporate limits of Troy and since then many others have suffered a similar fate, though not so many have died the last few years on account of the large amount of spraying done in different parts of the city for private parties. Even now it is possible to go into sections of the city and see within two or three blocks 50 to 100 or more dead elms. These are not aged trees that would have died irrespective of attack by insects, but are in most cases trees which a few years ago were as thrifty and vigorous as anyone could desire.

The story of the city of Watervliet has been virtually that of Troy except that less effort has been made to check the pest; also, as a large proportion of the elms in Watervliet were of the American or white variety on which the beetle does not thrive so readily, the destruction was not quite so rapid. It hardly seems possible, however, that fewer than 1500 magnificent trees have been killed or practically ruined by this insect in Watervliet. A brief note published in December 1900 in one of the Albany papers is of value because it gives the testimony of one who probably had little idea of the true cause of the condition complained of. Under Watervliet items was a short paragraph calling attention to the fact that numerous dead trees were a menace to the safety of pedestrians and stating that they were to be found on almost every block in the city. It might further

have very truthfully added that this condition was almost entirely due to the destructive work of the elm leaf beetle.

Practically the same story has been repeated here and there in small towns along the Hudson river valley where this pest has established itself in force; and, unless the insect is checked on its advent into a village, this is likely to be the record whereever it makes its way.

Inaction means death to the elm. The defoliation of a tree in midsummer is a serious injury since the leaves are breathing organs, and if this occurs for successive years even once a season, the early death of the elm may be expected; when it occurs two or even three times in a summer, it is very easy to see that the danger to the tree is increased manyfold.

Such is the record of the elm leaf beetle in this section. The time to control this pest is not after it has become enormously abundant in a city or village and has seriously weakened or nearly destroyed the majority of the elms; the work should be begun at the outset and in the future the insect prevented from establishing itself in large numbers in any uninfested city or village in New York. Village improvement societies and public spirited individuals interested in the welfare of a community where this beetle occurs would do well to undertake at least an educational campaign against it.

It is comparatively useless to hope that in the course of a few years the pest may not be so destructive. It shows a remarkable vigor and prolificacy in our climate. At Washington D. C. it has been known for a long series of years and is still very injurious. In New Jersey, New York city, New Haven Ct. and other localities it has been found necessary to spray the trees with a poisonous mixture in order to avert serious injury. Parasites, diseases of various kinds and predatory enemies seem to have little effect in reducing its numbers.

Distribution. The insect, as stated by Dr Howard, is found over a large part of Europe, but it is abundant and destructive only in the southern portions of Germany and France and in Italy and Austria. The records of the earlier entomologists indicate that the beetle must have made its way to this country about 1834, because in 1838 it was reported as very injurious to elms in Baltimore Md. Its southernmost range has been given

by Dr Howard as Charlotte N. C., and Prof. Webster records having found it north of Salem Mass. It has made its way as far west as Kentucky, at least. Its progress up the Hudson is interesting to follow, indicating as it does, its distribution along the lines of travel. In 1879[1] it was abundant and destructive at Newburg, 12 years later it was reported to this office from Poughkeepsie, in 1890 from Hudson, in 1891 from New Baltimore and in 1892 it had reached Albany and Troy.

It was found at Mechanicville in 1896 by Dr Howard and that same year larvae in considerable numbers were discovered by the writer at Averill park in the town of Sandlake about 7 miles southeast of Troy, the beetles evidently having been transported thither by the numerous electric cars running to that place. The writer also located the pest in 1900 at Hoosick Falls, Rensselaer co. where it had inflicted considerable injury the preceding year, and he found that it had established itself pretty generally in the towns of Stillwater, Schuylerville, Salem and probably Greenwich. Its presence at Salem and its being found at Saratoga in numbers in 1902 indicate a possibility of still farther progress north, though there were reasons for hoping that it would not be very injurious north of Mechanicville, except possibly in an unusual season.

The occurrence of this insect at Oswego, Hastings and Rochester, brought to my notice through Dr Howard, is a much more serious matter. Prof. C. S. Sheldon of the Oswego normal school states that he has examples of it taken at Oswego in 1896, and Prof. M. H. Beckwith of Elmira reports that he has known it to occur for several years in considerable numbers in his locality. It is also extending its range through the Mohawk valley, having recently been found in considerable numbers at Schenectady.

These last records are of very great importance since they show that the insect has already established itself in several widely separated localities in the western portion of the state and we have no good reason for thinking that it will not, in the course of a few years, be as injurious in that section as it has already proved in the Hudson valley.

1 Unfortunately most of these dates indicate only the time when the ravages of the insect were serious enough to attract the attention of someone, and so only approximately the year of its arrival.

It has spread over a large proportion of Connecticut and into Rhode Island. It had made its way up the Connecticut river valley to Springfield by 1891 and to Amherst by 1895. It has now attained a rather general distribution over the eastern portion of Massachusetts, having been recorded by Mr Kirkland from Worcester and towns in that vicinity, Ayer, Groton and places in the eastern and southeastern part of the state. It has also been found in a number of places in western Massachusetts.

The above records indicate most clearly that this pest has not made its way to all portions of New York state where it may be expected to thrive. The climate of the upper austral life zone seems to agree with the insect, judging from its abundance and the number of broods in Albany and vicinity. The area within the state embraced by this zone is rather crudely represented on pl. 2, which was first published in the 11th report on the injurious and other insects of the State of New York for the year 1895. Briefly, it embraces Long and Staten islands, the valley of the Hudson river north about to Saratoga and a large portion of the northwestern and central part of the state adjacent to Lake Ontario and including Oneida, Cayuga and Seneca lakes and neighboring bodies of water. This insect will probably make its way along the lines of travel to most of the cities and larger villages lying within the above limits. The fact of its having become established at localities not yet included within this zone indicates that it may have a somewhat wider range, though climatic conditions will probably prevent its becoming destructive outside this area.

Description. The work of this pest is so striking as to excite the attention of even the most casual observer. The majority have little idea of the appearance of the insect in its various stages and but faint conception of its life history. In order to control it, it must be recognized and its nature understood to a certain extent.

The parent insect may be recognized by aid of the colored figures (pl. 1, fig. 5, 6) though care should be taken not to confound it with the striped cucumber beetle Diabrotica vittata Fabr., which it resembles in a general manner. The elm leaf beetle is about ¼ inch long with the head, thorax and

margin of the wing-covers a reddish yellow. The coal-black eyes and the median spot of the same color on the head are prominent. On the thorax there is a median black spot (not infrequently two triangular ones) of somewhat variable shape and size and a pair of lateral ovoid ones. The median black line of the wing-covers is separated from the broad lateral stripes of the same color by a variable greenish yellow. The elytra or wing-covers are minutely and irregularly punctured and bear a fine pubescence and at the base of each elytron there is an elongated black spot in the middle of the greenish yellow stripe. The markings are usually constant in the adult but the color is quite variable during life and changes more or less after death. Some beetles emerging from winter quarters have the conspicuous greenish yellow stripes of the wing-covers nearly obscured by black. The antennae are a golden yellow with more or less brownish markings. The legs are yellowish with the tibiae and tarsi marked with brown. The under surface of the head and prothorax is yellowish, that of the metathorax and abdomen black.

The orange yellow eggs are deposited in irregular rows side by side, forming clusters of from five to 26 or more on the under surface of the leaf. Several of these are shown natural size in fig. 7. Each egg is somewhat fusiform, attached vertically by its larger end and with the free extremity tapering to a paler, rounded point (pl. 1, fig. 1, 1*a*). Under a powerful lens the fine reticulations of the eggshell are easily seen.

The recently hatched larva (pl. 1, fig. 2) is about $\frac{1}{20}$ inch long, with the head, thoracic shield, numerous tubercles, hairs and legs jet black. The integument between the tubercles is a dark yellow. The tubercles are so large and the hairs so prominent that the prevailing color of the larva at this stage is black. As the larva increases in size and molts, the stiff black hairs become less conspicuous and the yellowish markings more prominent (pl. 1, fig. 3) till the last stage. A full grown larva is about $\frac{1}{2}$ inch long, more flattened than in the earlier stages, with a broad yellowish stripe dorsally and a narrower stripe of the same color on each side, the yellow stripes being separated by broad dark bands thickly set with tubercles bearing short, dark colored hairs. The dorsal yellow stripe is broken on each side

by a subdorsal row of dark tubercles, which increase in size posteriorly. The lateral yellow stripe includes a row of prominent tubercles with dark tips bearing short hairs of the same color. The predominating color of the ventral surface is yellow.

The pupa (pl. 1, fig. 4) is bright orange yellow, about $\frac{1}{5}$ inch long and with a very convex dorsal surface which bears transverse rows of stout, inconspicuous setae.

Life history. In order to control this insect successfully it must be known and its habits understood. Trite though the preceding may appear we have observed men in several places spraying for this pest without accomplishing anything for the simple reason that they did not understand the fundamental principles of fighting insects. In one case the trunk of the tree was sprayed while the grubs were on the leaves; in another paris green and water was used when kerosene emulsion or whale oil soap solution should have been employed.

The beetles pass the winter in attics, sheds, outhouses and various other sheltered places. With the advent of warm weather in the spring they emerge from their retreats and may be found on the walks during the sunny portion of the day or on the windows of houses, vainly trying to escape. Even as early as May 12, numbers of these beetles were to be seen in 1898 on the office windows of the fourth story of the capitol, showing to what a hight they will fly in seeking secure winter quarters. On the appearance of the leaves, the last of April or the early half of May in the latitude of Albany, they fly into the trees and eat irregular holes in the foliage (pl. 1, fig. 9). After feeding some time, and pairing, the orange yellow eggs are deposited on the under surface of the leaves in clusters of about five to 26. The period of oviposition of the overwintered beetles extends from the latter part of May throughout the greater part of June in the vicinity of Albany. The duration of the egg stage in July averages about five days; in cooler weather it may be longer. Feeding and oviposition continue for several weeks in the spring, probably four to six. During this time the beetles consume a large amount of foliage, which is evidently necessary for the development of the eggs, as clusters are laid every day or two till the full complement, which is in the neighborhood of from 431 to 623, is discharged.

As there seems to have been no attempt, at least in this country, to determine the prolificacy of this insect, the following may be of interest. May 31, 1898, two heavy gravid females were isolated, provided with plenty of food, and the eggs removed and counted nearly every day. The results are tabulated below.

Record of eggs deposited by two elm leaf beetles [1]

	FEMALE IN VIAL		FEMALE IN TUMBLER	
DATE	CLUSTERS OF	TOTAL	CLUSTERS OF	TOTAL
June 1	(2)	29	(4)	42
2	.....	....	.....	....
3	9, 9, 14	32	18	18
4	.....	....	.....	....
5	.....	....	.....	....
6	18	18	26, 21	47
7	.....	....	.....	....
8	15	15	4, 26	30
8 (2 D. M.)	20	20	.....	....
9	.....	....	27	27
10	20	20	(3 P. M.) 3, 31	34
11	23	23	.....	....
12	.....	....	.....	....
13	11, 13	24	3, 7, 8, 11, 15, 19	63
14	31	31	.....	....
15	16, 5	21	14, 27	41
16	28	28	30	30
17	.....	....	32	32
18 (absent)	.....	....	.....	....
19	26, 30	56	10, 26	36
20	2, 6	8	36	36
21	3. 18	21	6, 25	31
22	2, 20	22	4, 31	35
23	27	27	1, 2, 11, 7, 13	34
24	.....	....	.....	....
25	.....	....	.....	....
26	.....	....	.....	....
27	5, 7, 9, 15	36	13, 21, 32	66
28 (beetle dead)	.....	....	(beetle dead) 4, 17	21
Totals	.....	431	.....	623

1 The examinations were made as a rule between 8.30 and 9 a. m. though occasionally, when eggs were seen in the afternoon, they were recorded at the time indicated in the table. The dates in italics fell on Sunday and usually no observations were made then.

The above records have a very vital bearing on remedial measures. From June 1 to 11 from 15 to 47 eggs were generally deposited every other day. The 12th being Sunday the beetles were not attended, but two or more clusters being found with each on the following morning, probably one or more were deposited on Sunday.

The records show that from June 12 or 13 to 23 there was a marked increase in the number of eggs, eight to over 40 being as a rule deposited daily. The record of the beetle confined in the vial indicates a discrepancy greater than the facts warrant. It was impossible to attend the insects on the 18th, so it appears as though two days had been skipped by one beetle and one day by the other, whereas it is probable that there was but a day that the beetle in the vial did not deposit eggs, and the record of the other was probably unbroken, eggs being deposited daily.

During this short period of 10 or 11 days—June 12 or 13 to 23—there were deposited over half the total number of eggs produced during the 28 days the record was kept, the figures being 330 and 338 respectively or an average of over 21 and 30 eggs a day. The average number deposited during the first 11 days of the month are 14 and 18 respectively, which shows that there was an increase in the daily average of one half or more in the case of each beetle after June 11. Those deposited after the 25th were apparently the last efforts of the insects to provide for the perpetuity of their kind, though the quality of the eggs had not deteriorated so far as observable.

The continued oviposition and the prolificacy of the beetles is strikingly shown in this record. They were abroad in numbers by May 12, 1898, and oviposition began about the 25th, so the record of these two individuals is probably lower than the normal as they may have deposited several clusters of eggs before being captured. They were both supplied with fresh leaves from day to day and the eggs removed and counted as soon as detected. The female producing the smaller number of eggs was confined in a small, corked vial, while the other enjoyed the freedom of a jelly tumbler. The difference in condi-

tions undoubtedly had some influence on egg production and the protection from unfavorable weather conditions enabled the beetles to approximate the maximum quota of eggs. The record is of great value since it shows clearly how long oviposition may be continued by a single individual, and shows that if the adult beetles can be killed by thorough spraying any time before this period of greatest reproductive activity, which was about June 11 in 1898, the deposition of a very large number of eggs can be prevented, with correspondingly less danger from the grubs or larvae.

The grubs emerge from the eggs early in June or about five or six days after oviposition, and soon begin to feed on the under surface of the leaves, producing the familiar skeletonized appearance well represented on pl. 1, fig. 8 and pl. 7, fig. 1. This is caused by their eating the softer under part, the upper epidermis and the veins being left. The result of their feeding is so characteristic that it is easy to detect their presence by the semitransparent places in partly eaten leaves and by the skeletonized appearance of the foliage which has been more severely attacked.

The grubs complete their growth in 15 to 20 days in summer (in cooler weather the time may be greatly extended), become restless, forsake the leaves and descend the limbs and trunks to a greater or less extent, seeking proper shelter for pupation. In warm July weather seven days are passed in this state, in September the time is extended to 12 days and in October to 24. The descent of the larvae of the first brood usually occurs in Albany the latter part of June; in 1896 some were observed descending June 19, and beetles of the second brood were taken June 30. The oviposition of the second brood of beetles begins about the middle of July. From that date till late in the autumn it is possible to find the eggs of this insect most of the time in some part of the city. The beetles are naturally attracted by a fresh growth of foliage and it is on the trees throwing out a second or a third crop of leaves or on those not attacked earlier in the season that the eggs of later generations

are found most abundantly. Most of the second brood of larvae complete their growth about the middle of August, becoming adults the latter part of the month. If there is an abundant food supply a partial third generation may be produced. In 1896 numerous eggs were found on elms in Troy the first part of September. This was probably the case in Albany also, as indicated by the large numbers of full grown larvae descending near the middle of October certain Scotch elms which had been practically uninjured in the early part of the season.

This latter occurrence shows most conclusively that the larvae are able to develop on old leaves. The persistent breeding of the insect late in the autumn is shown by the presence of full grown larvae on elm trunks October 31 and by the finding of living pupae on November 7 in 1896, and in 1897 on the still later date, November 16.

Number of generations. The detailed observations of 1896 to 1898 have established beyond question the possibility of two well marked generations annually and the occurrence under favorable conditions of an incomplete third brood at both Albany and Troy. In these two cities the insect has continued breeding as long as the elms afforded sustenance. There is every reason for believing the same to be true in adjacent cities and villages. This is the more remarkable since Dr Smith records but one brood a year, or one and a partial second, at New Brunswick N. J., about 150 miles to the south. As is well known, most insects are more destructive soon after their introduction than in later years. This may be accounted for by the fact that in time native parasites, diseases and other natural checks gradually assert their power on new comers. An insect's freedom from natural enemies might have some effect on its prolificacy, and possibly on the number of generations. It will not only be of interest but of great practical importance to ascertain by observations whether this beetle continues to produce two or three generations yearly in this latitude.

Habits of beetles and larvae. A knowledge of certain habits of this insect are of great value in controlling it. Its hibernation

affords no vulnerable point as the beetles are then too scattered to admit of effective work against them. They feed on the young leaves in the spring for two or three weeks and when abundant may cause considerable injury. The irregular round holes in the foliage (pl. 1, fig. 9 and pl. 7, fig. 2) are an indication of the presence of the beetles, and the amount of injury gives some idea of their abundance. Under exceptional circumstances they may eat the under surface of the leaves, refusing the veins and tough upper epidermis. This is only when the foliage is unusually hard and dry.

One habit of much importance which the adult insect possesses is its disinclination to fly a great distance. Its instinct to remain near one spot is so strong that it spreads very slowly indeed. This is clearly shown in its taking seven years to make its way in numbers from the point where it established itself first in this city to Washington park, a distance of less than 1½ miles. We have repeatedly seen European elms badly defoliated and within 50 feet others of the same species would be hardly affected. In three years (1895-98) it made its way along certain rows of European elms in Albany at the rate of about a block a year.

The larvae are very rarely found on the upper part of the leaf; they appear on the under surface and feed there almost exclusively. It is also evident that in most cases trees are attacked near the top, probably because the foliage of the upper portion is more tender and clean. This is well shown on pl. 3, where the dead tips are high, showing conclusively the preference the beetles have for the younger leaves.

The larvae forsake the leaves after attaining their growth and may be found crawling along the limbs and trunk. If the tree has comparatively smooth bark, a far greater portion make their way to the ground in search of proper shelter while passing through the pupa stage, than if it has a rough bark, which affords numerous secure crevices in which the final changes may be effected. At this time the trunks of infested trees present an interesting sight as thousands of the grubs

crawl up and down the shaggy bark. Occasionally their numbers are so great as to give a distinct character to the surface they are moving over, presenting a peculiar grayish yellow mass of motion enlivened here and there with an orange yellow pupa. A few days later the pupae are more numerous on the trunk and around the base of the tree and adjacent shelter, where they may sometimes be found in golden layers nearly an inch deep, interspersed here and there with a dark larva. Many larvae do not descend the older trees but take refuge in the crevices of the bark, or, if there are overhanging limbs, may drop in numbers from the tips of the branches. Many are content to transform in the gutters, others seek shelter in the crevices of the sidewalks and large numbers cross wide spaces and pile themselves up against a wall or a fence or around any sheltering bush or weed.

SPECIES OF ELMS ATTACKED

It will be observed in most localities that the American elm, Ulmus americana, is comparatively exempt from the attacks of this insect. Sometimes the beetles will make their way from adjacent European elms and seriously injure the American species and, after they have once become established, the but partially migratory habit of the beetle insures attack for a few successive seasons at least. The English elm, Ulmus campestris, and the Scotch elm, Ulmus montana, usually suffer most seriously, while our native species are but little affected. This was very noticeable in Troy and Lansingburg. European elms are numerous in the former place and the work of the elm leaf beetle is conspicuous over the greater part of the city, but as one proceeds northward into Lansingburg American elms abound almost to the exclusion of the foreign species and evidences of the pest are comparatively rare. Again, in 1895 the American elms of Albany showed very little injury by the insect. The next year trees here and there gave evidence of a serious attack and in 1897 a much larger number of the American elms was seriously injured than in the preceding year. The numerous American elms in Water-

vliet have been very severely injured, though the relatively few European elms suffered more.

No species of elm grown in this country is exempt from attack though there is considerable variation in the degree of injury inflicted on the different kinds. The relative liability to attack is apparently a variable quantity in different localities. According to Dr Howard's observations, the American elm suffers more from the insect than does the Scotch, the English species being the favorite, while in both Albany and Troy the injuries to the English and Scotch varieties were about equal, the latter suffering more in many instances, while the American elm was eaten to a much less degree.

AN ASSOCIATED INSECT

The elms, particularly the European species, in Albany, Troy and other places along the Hudson river are most unfortunate in suffering from the attacks of another imported insect known as the elm tree bark louse, Gossyparia ulmi Geoff. This was first discovered in this country at Rye, Westchester co. N. Y. in 1884, on the nursery stock of Mr Charles Fremd. It is now known to occur in a number of localities in the Hudson valley, being generally distributed over Albany, Troy and adjacent towns, and ranging north to Greenwich. It has been received by the writer from Ogdensburg, St Lawrence co. It has also become established in the vicinity of Boston and at Amherst Mass. and Burlington Vt. Other recorded localities are Washington D. C., Michigan agricultural college, Carson City Nev. and Palo Alto Cal.

Injuries and characteristics. The injurious nature of this bark louse in our latitude has been abundantly demonstrated the past few years in conjunction with the work of the elm leaf beetle. The affected trees are easily recognized in midsummer by their blackened appearance, which is caused by a growth of the fungus Coniothecium saccharinum Peck in the honey dew covering the foliage, the limbs and the ground beneath. The minute drops of the secretion may easily be seen in sunlight falling in showers from the clusters of insects,

giving an idea of what a drain this species must be on a tree's vitality. The limbs which have harbored the bark louse for a few years begin to die, the tree itself shows signs of weakness, and when it is attacked by both the elm leaf beetle and the bark louse, its destruction follows in a few years.

Description and life history. The adult females are rather conspicuous during April, May and June. They may be found on the under sides of the smaller branches, frequently clustered in masses and appearing not unlike certain lichens. Each at this time is about $\frac{1}{10}$ inch long, oval in outline, with the extremities slightly pointed, and if crushed causes a reddish stain from the contained ova. The body is surrounded by a mass of white, woolly secretion and the segmentation is also indicated by the same substance, as shown in pl. 8, fig. 1. The minute yellow young make their appearance early in July and soon settle for a time on the greener twigs and along the principal veins of the leaves. Occasionally a greenish twig will be almost yellow on account of the large number of young settled on it. In the autumn the back of the partly grown bark louse is covered with spiny processes which excrete a protective, whitish waxy matter. Most of the insects forsake the leaves at this time and settle for the winter in crevices of the bark. The females molt for the last time early in April, and the males spin their oval cocoons (pl. 8, fig. 2). The delicate, four winged reddish male is rarely seen, though of particular interest from its presenting a partially developed form known as the pseudimago. The latter was present in large numbers May 10, 1900, while the perfect males were not found till the 21st.

Means of distribution. As the slender males only are winged, the insect is dependent largely on various outside agencies for its distribution. It has most probably been carried to Nevada, California and other distant localities on infested nursery stock, but this does not explain its general occurrence in such cities as Albany and Troy. Its distribution in these two places, at least, appears to have been largely effected by the aid of the English sparrow and other birds; the active young can easily

crawl on the foot of a bird and thus be transported from one tree to another. Other insects may also to a certain extent transport them and some, falling with the leaves, might successfully make their way up another tree; the chances, however, are against the latter method.

SECONDARY ATTACKS BY INSECTS

It is well known to students of nature that an enfeebled tree apparently invites attack by certain insects which seem to find

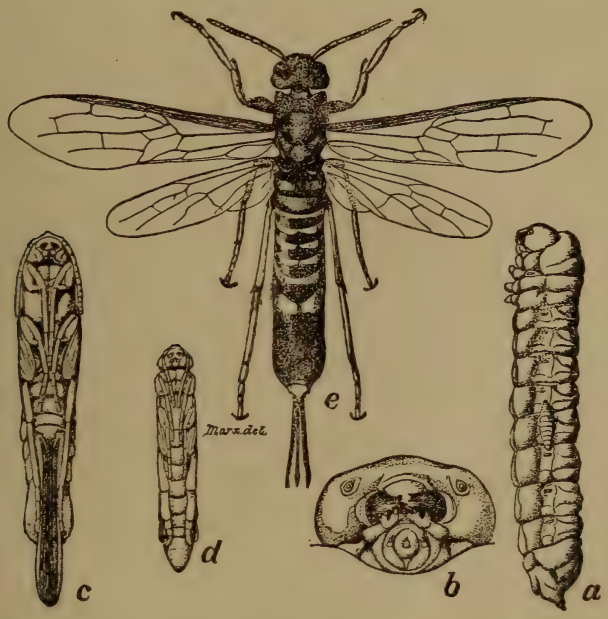

Fig. 1 Tremex columba: *a*, larva showing the Thalessa larva fastened to its side; *b*, head of larva; *c*, pupa of female; *d*, male pupa; *e*, adult female; all slightly enlarged. (After Riley, *Insect life*, v. 1, fig. 39)

in the unhealthy tissues conditions peculiarly fitted for their development. The ravages of the elm leaf beetle have encouraged certain of these pests to a marked degree. One of the most common and injurious is known as the pigeon Tremex, Tremex columba Linn. This insect is a magnificent four winged fly about 2 inches long, with a wing spread of 2½ inches and a prominent horn at the extremity of the abdomen from which it gets the common name of horn tail. It may be recog-

nized by its cylindric dark brown abdomen with yellow markings as represented in fig. 1.

The female deposits her eggs in the trunks of sickly trees, where the larvae run large cylindric burrows. Many elms in both Albany and Troy show numerous holes caused in this way. This borer has a deadly parasite in the lunate long sting, Thalessa lunator Fabr. This beneficial insect is of great aid in keeping the Tremex under control. The remains of 13 ovipositors were found by the writer in the trunk of one small elm. In their efforts to reach the numerous borers in the tree, the females had driven their long ovipositors so far into the wood that they were unable to withdraw them.

Another insect which infests debilitated elms is known as the elm borer, Saperda tridentata Olivier. The larvae of this beetle run their burrows under the bark and in the sapwood of the trunk, not many penetrating to a greater depth than an inch. Their burrows frequently become so numerous as to girdle trees two or three feet in diameter. An infested elm may be recognized by the patches of unhealthy bark; in case of a bad infestation large pieces become loose and scale off easily. The beetle is usually less than $\frac{1}{2}$ inch long, and of a dull slate color, with the thorax and wing-covers margined with dull orange (fig. 2).

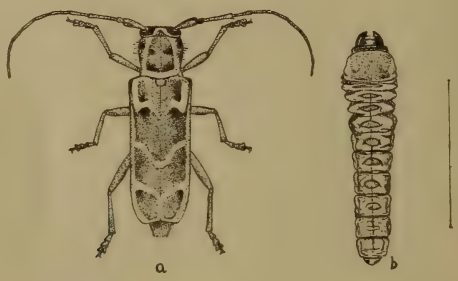

Fig. 2 Saperda tridentata (twice natural size)

NATURAL ENEMIES OF ELM LEAF BEETLE

The natural checks serving so well to keep thousands of insects under control which otherwise would be very destructive, are unable to reduce the numbers of this beetle to a relatively harmless figure. One of the more important natural agents is

the fungus Sporotrichum entomophilum Peck, which has been observed developing on many beetles in this city. Like the disease of the chinch bug caused by the allied fungus, Sporotrichum globuliferum Speg., the one attacking the elm leaf beetle requires moist atmosphere for its development. Beetles in close breeding jars, under the bark of trees or in similar damp places succumb readily to the disease. Climatic conditions are not ordinarily favorable to the rapid growth of this fungus, so it has a relatively slight value as a natural check on the elm leaf beetle.

Several insects are known to prey on this pest, its pupa or its larva. Three beetles, Platynus punctiformis Say, Quedius molochinus Grav. and Chauliognathus marginatus Fabr., feed on this species as recorded by Riley. A fly, Cyrtoneura stabulans Fall., destroys many pupae in Washington. In this latitude the half grown larva of Podisus spinosus Dallas has been observed with an elm leaf beetle grub on its extended beak, and it probably preys extensively on the larvae, since in Washington all stages are known to attack it. Mr Kirkland has recorded two other species, Podisus serieventris Uhler and P. placidus Uhler as preying on this pest. He also found Stiretrus anchorago Fabr. feeding upon the larvae. A small capsid, Camptobrochis grandis Uhler, sucks the eggs. Larvae of lacewing flies, also called aphis lions, are frequently found on leaves with the young of the elm leaf beetle, and are reported by Riley to feed on both eggs and larvae. Mites have been observed by the writer near egg clusters that had suffered injury. This insect finds an enemy in the southern portion of its range in the praying Mantis, Stagmomantis carolina Linn. It is very probable that the European praying Mantis, Mantis religiosa Linn., recently established in a number of localities in the state through the efforts of the writer, will also prey on this injurious beetle.

Though we have seen nothing of the kind in this vicinity, one gentleman affirms most positively that the English sparrow

feeds on the elm leaf beetle larvae, having repeatedly observed it picking them off the trunks of the trees. If the sparrow has this habit, it offsets to a certain extent its many bad features.

REMEDIES

The most satisfactory method of controlling this insect is by poisoning the foliage. The objection heretofore urged against this means has been the expense, and it still applies to a certain extent in the case of the private individual with but few trees to care for. Aside from the cost of the necessary apparatus, the operation of spraying even large shade trees is not so expensive as is commonly supposed; and valuable results may be obtained with a comparatively inexpensive outfit, though the cost for each tree may be increased.

Cost of spraying elms. We have taken some pains to ascertain the precise cost of spraying a tree in the hope of encouraging those to whom the expense seems a serious item. It is pleasant to record that it is much lower than had been supposed previous to the time this bulletin was originally prepared; more recent data confirm the fact. Dr Smith, of the New Jersey agricultural experiment station, kindly supplied the following data in 1898. The elms on the college campus at New Brunswick are 50 to 75 feet high and were sprayed at odd times by the janitors, about an hour being required by two with force pump, tank and ladders to treat one tree. The poison necessary for each spraying was worth about 6c. It will thus be seen that the cost for each tree would be between 36c and 56c, varying with the price of labor. In New Brunswick the trees were sprayed at a contract price of $1 for the season, the understanding being that they were to receive three treatments if necessary. The contractor prepared the outfit, furnished the material, did the spraying at the price mentioned and had a neat margin remaining.

The cost of spraying elms in Albany in 1898, aside from wear and tear of the apparatus, was about 15c a tree for each spraying. This average was based on one or two days work and probably would not hold for the season. It is very likely that it would have paid to give each tree a little more time, which

would have brought the average cost up somewhat. The elms of Albany range from 20 to about 70 feet in hight, though most of them are over 50.

The average cost of one spraying in Albany in 1900 was about 22c a tree. The spraying was done with an apparatus, to be described later, and under civil service regulations, which require men to work but eight hours a day. Two power spraying outfits under one foreman's direction constituted the force. It would be possible in private work to reduce the force somewhat and have one man do duty both as motorman and driver. A little more selection could also be exercised and possibly more efficient men secured than can usually be obtained under civil service regulations.

Mr H. W. Gordinier of Troy found that in contract work in the village of Lansingburg, where he sprayed all the trees, the average cost a tree for each spraying was 23c. This figure, however, was raised considerably in his work in Troy where the trees were sprayed at the expense of private parties and there was necessarily much running hither and thither; under these conditions it ranged from 50c to 60c a tree, the cost depending on the size and the number in one locality.

The saving in cost shown by the above figures, not to mention the greater benefit to the public, particularly in the poorer sections of a city where shade trees are most needed and where they are usually neglected, is a strong argument in favor of such spraying operations being done under village and municipal authorities. The more general and thorough the work, the more satisfactory the results.

Proper apparatus. In order to do this work successfully one must possess a force pump capable of throwing a stream some distance, a number of feet of hose and a nozzle that will discharge a rather fine spray. There must also be something to hold the poisonous mixture and a ladder facilitates the work of application greatly.

One of the best arrangements for hand work is most probably found in the spraying outfit on wheels so that it can be readily

moved from place to place (pl. 6). In most cases this takes the form of a box or barrel to which a force pump is firmly attached, and is either provided with wheels or designed to be placed in a wagon. It is necessary to have 25 to 50 or more feet of $\frac{1}{4}$ or $\frac{1}{2}$ inch hose when spraying tall trees, while the addition of a 10 to 25 foot metal extension adds materially to the value of the apparatus. It is also necessary to have a good nozzle that will not clog, but will produce a fine spray and can be quickly adjusted to throw a coarse spray some distance if necessary. Such an outfit is of great service to any individual having considerable spraying to do and it could undoubtedly be used to advantage by those desiring to make a business of spraying in a small way, as for example the treating of trees here and there for those in cities wishing their trees sprayed and not willing to purchase the necessary apparatus.

In the extended work against this insect conducted by cities and villages it is desirable to have apparatus that will admit of more rapid work. This has led to the refitting of retired fire engines and the designing of more or less cumbersome outfits for the purpose. In all cases these makeshifts have been successful, though they are not so satisfactory in operation as those specially fitted for the purpose. One of the best forms of apparatus yet designed for spraying trees is that constructed under the direction of Dr E. B. Southwick, entomologist of the department of public parks of the city of New York. This is the form used in Albany. The whole outfit is represented on pl. 5. It consists of a Daimler gasoline motor operating a Gould force pump. The motor and pump, weighing but 300 pounds, can be placed in the bottom of a spring wagon along with the 100 gallon tank containing the poisonous mixture. This motor has the advantage of being almost noiseless in operation and is scarcely noticed by passing horses. It is very inexpensive to operate, as a gallon of gasoline is sufficient for a day, and it requires so little attention that a tyro can run it. The smallest size Gould three piston pump is the one used with the motor, though Dr Southwick now recommends a larger one

in order to utilize the power more fully. A complete power spraying outfit, aside from horse and wagon, should not cost over $500, the price naturally varying with market conditions and quality of materials used. Four lines of hose can easily be supplied though in most places in Albany not more than two can be used to advantage.

Some other apparatus in addition to that usually supplied with spraying outfits is necessary. Several ladders or some convenient arrangement for getting up into trees is almost essential unless the spraying wagon has one of the elevating platforms such as are used by electric car companies on repair outfits. Two power spraying outfits constructed for the village of Saratoga in 1899 were provided with these elevating towers and these were found to be very effective and economical. The cost of spraying for the forest tent caterpillar which, by the way, need not be done so carefully as for the elm leaf beetle, was but 17¼c a tree and considerable of this saving was attributed to the elevating towers. In this instance 5667 large maple trees were sprayed and practically all in the village were treated, thus enabling the operators to save time in every possible manner.

Time and manner of spraying. Though it is easy to state the proper time to spray, in many cases it is exceedingly difficult to have the recommendations properly carried out. The beetles feed in the early spring on the young foliage for a considerable time before any eggs are developed and eat for a day or two between the deposition of the clusters. It therefore follows that if the partly unfolded leaves are sprayed at this time the beetles can be killed and the production of eggs prevented to a large extent. This is very desirable, for if at all numerous the beetles injure the foliage considerably. A number of arsenical poisons can be used in the control of this insect with very good results but the experiences of the last four years have demonstrated the great superiority of arsenate of lead for this work. This is a preparation made by combining acetate of lead and arsenate of soda. It may be prepared as follows: dissolve 11

ounces of acetate of lead in four quarts of water in a wooden pail and four ounces of arsenate of soda (50% purity) in two quarts of water in another wooden pail. As the acetate of lead dissolves rather slowly in cold water the process can be hastened by using hot water. Pour the solutions in enough water to make 80 gallons.

It was at first advised to prepare this poison in the manner indicated above but the difficulty of getting chemicals of the same grade of purity year after year and the ease with which dealers in these substances may prepare this insecticide, has led to the introduction of several brands of arsenate of lead in the prepared paste form. These preparations have been found more convenient than the homemade article and generally speaking their use is advisable. The crystalline arsenate of lead is not in proper condition to use as an insecticide and therefore it is necessary to get the specially prepared article.

The value of arsenate of lead over other poisons lies in its adhesiveness to the foliage—it frequently remains on the leaves nearly an entire season in spite of many rains—and in the fact that it can be applied in almost any amount without danger of injuring even the most delicate leaves. Paris green, london purple and similar arsenical poisons operate more quickly than arsenate of lead but they are also readily washed off by rains, and in the case of an insect like the elm leaf beetle, which feeds for an extended period, it is much better to apply the more adhesive preparation even though the cost be somewhat greater. The necessary amount of prepared arsenate of lead is usually stated on the package and it varies somewhat with the method of manufacture.

The first spraying, as stated above, should be given as soon as the leaves commence to develop and usually it will be necessary to repeat the treatment at the time the young larvae begin their work, though after the insect has once been brought well under control in a locality, possibly a single thorough spraying each year for the beetles may be sufficient. Experience has shown that in a locality where all the elms are thor-

oughly sprayed it may not be necessary to treat them again for two years.

The second spraying should occur at the time the young are beginning to hatch, which in this latitude is about the first week in June. The poison should be applied to the under surface of the leaves. This is because the larvae feed only very exceptionally on the upper surface of the foliage or even break the upper epidermis. Consequently it is impossible to poison them unless the insecticide be thrown on the under surface. The larvae succumb to the poison more readily than the beetles and it is therefore not necessary to use so concentrated a mixture in the later sprayings.

The necessity for subsequent sprayings depends largely on the manner in which the previous work has been done. Much depends on the man who holds the nozzle, even though he be under the eye of one who understands the business. The mixture should be applied evenly in a rather fine spray and so far as possible to every leaf. If the poison be applied thoroughly and at the right time, two sprayings should be ample to keep the beetle under control. Otherwise it may be necessary to spray for the second and even the third brood. The proper time for later arsenical sprayings must be determined by observation. The spraying for the second brood should be done in Albany and Troy about the latter half of July.

A PALLIATIVE MEASURE

It frequently occurs that for some reason spraying with poison can not be resorted to readily. The habits of this insect are such that at certain times large numbers can be destroyed with little labor, as has been pointed out year after year. But it is well to understand that such a measure is not a remedy in the true sense of the word; it is simply a palliative. Everyone interested in the welfare of his shade trees should at least destroy the thousands of larvae and pupae on the trunks or around the base of infested elms. If the base of the trees, their surroundings and other adjacent shelters be thoroughly drenched with boiling water or sprayed with kerosene, kero-

sene emulsion or some similar preparation, thousands of these insects can be killed. As it requires six or seven days for the larvae to pass through the pupal stage to beetles, this operation need not be performed oftener than once in five days to insure the destruction of all that have pupated within reach of such a measure. The nearly simultaneous descent of the grubs is very favorable to this way of checking the insect and reduces the necessary labor to a minimum. To make this method more effective, it has been recommended to inclose a limited smooth area around each infested tree, preferably cemented, boards being arranged to prevent the larvae from escaping to shelters where they could less easily be destroyed. Such an inclosure might be advisable around small trees with relatively smooth bark and no overhanging limbs, but it would hardly pay to treat larger trees thus on account of the large number of larvae pupating in the crevices of the bark or dropping from the tips of overhanging limbs. The great objection to fighting the insect at this stage is that the injury has already been accomplished, but to do even this is much better than to allow it to go on unchecked, because it must have some influence on the future abundance of the beetle. The destruction of larvae and pupae around the base of the trunk may well be undertaken to supplement the spraying and thus secure the destruction of the largest possible number of the insects.

USELESS MEASURES

Though the life history of this beetle is well known, at least to entomologists, it is surprising how people will cling to some false idea, gained they know not where, of the method of fighting this or some other insect. One of the most persistent of these fallacies is that cotton placed around the trunk will protect a tree from the elm leaf beetle. Under certain conditions a band of cotton, tar or other substance will protect trees from some insects, but never from the elm leaf beetle. It should be understood that the parent insect flies up into the tree, feeds for a time and then lays the eggs from which the grubs emerge to commence their injurious work. The band can not have the

slightest influence in protecting the elm. It is only when the grubs are full grown that they are found on the trunks and then only on their way to seek shelter on the ground during pupation. If a band of any kind blocks the way to the ground they may transform on the tree or even in the meshes of the cotton band and fly away later. If the band is of tar or sticky fly paper large numbers of the grubs may be caught on its surface, but there will hardly be enough to pay for the trouble incurred.

Another so called remedy for the elm leaf beetle consists in boring a hole to some depth in the trunk, nearly filling it with sulfur or other preparation and then inserting a plug. This method of treatment or some modification of it is being brought forward every few years as one of the "sure cures." The destruction accomplished by the elm leaf beetle has encouraged at least one unscrupulous firm to advertise a modification of this method as a sure cure. The Elm inoculation company in 1895 treated many elms in Connecticut and 150 for one man in Westchester county, N. Y., charging 50c or more a tree. Chemical analysis showed their secret preparation to be nothing of value. This or any similar treatment may well be regarded suspiciously by any would-be investor. It is hardly necessary to add that such a remedy has no basis in scientific fact and similar recommendations should not be heeded unless they come through such channels that their authenticity can not be doubted.

REMEDIES FOR ASSOCIATED INSECTS

The elm bark louse belongs to Hemiptera, that large order of insects which take food only by suction through a fine proboscis from the underlying tissues. It is easily seen therefore that a poison applied externally to the tree, as for example paris green, would have no effect on this pest. The best remedy is one of the contact insecticides, preferably kerosene emulsion or whale oil soap solution. This should be sprayed on the under surface of infested limbs and foliage when the tender young are appearing. Kerosene emulsion may be prepared by dissolving a half pound of hard soap in a gallon of

boiling water; while yet hot add two gallons of kerosene and emulsify thoroughly by passing it rapidly through a force pump till it is white and has a creamy consistency. For the young, one part of this emulsion to 10 parts of water should be effective. Whale oil soap solution may be used in the same manner, a pound of the soap being dissolved in four gallons of water. These preparations could be applied in the autumn after the dropping of the leaves, but in this case the solutions should be about four times as strong. Small trees may be cleaned with a stiff brush, which might be made more effective by dipping it in one of the above solutions from time to time.

Preventive measures against borers are of much more importance than any remedies that can be applied. The trees should be kept in as vigorous a condition as possible and careful watch maintained for the first signs of boring, indicated by the detached grains of wood popularly termed "sawdust." When indications of their presence are found the larvae should be dug out if possible. A badly infested tree should be cut down and burned to prevent the insects from developing and the adults from making their way to other trees.

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EXPLANATION OF PLATES

PLATE 1[1]

Elm leaf beetle

Galerucella luteola Müller

FIG.

1 Cluster of eggs, much enlarged

1*a* Side view of single egg, still more enlarged

2 Recently hatched larva or grub, much enlarged

3 Full grown larva or grub, much enlarged

4 Pupa, much enlarged

5 Overwintered beetle, much enlarged

6 Fresh, brightly colored beetle, much enlarged

7 Leaf showing eating of larvae or grubs and a few holes eaten by beetles, eggs in clusters, cast larval skins and full grown larvae, natural size

1 Executed from nature, under the author's direction, by Mr L. H. Joutel of New York city, and reproduced from the 5th report of the commissioners of fisheries, game and forests through the courtesy of the commissioners.

FIG.

8 Leaf nearly skeletonized by grubs or larvae and on it two cast larval skins, natural size

9 Leaf showing holes eaten by beetles, natural size

PLATE 2

Upper austral life zone in New York state, which is the area likely to become infested by the elm leaf beetle

PLATE 3

Work of elm leaf beetle on Elm street, Albany, taken 15 June 1898.

PLATE 4

Work of elm leaf beetle on Jacob street, Troy, taken 15 June 1898.

PLATE 5

Power spraying outfit at work in Albany, taken 15 June 1898

PLATE 6

Hand spraying outfit at work in Albany, taken 15 June 1898

PLATE 7

1 Work of elm leaf beetle larvae, showing characteristic skeletonizing

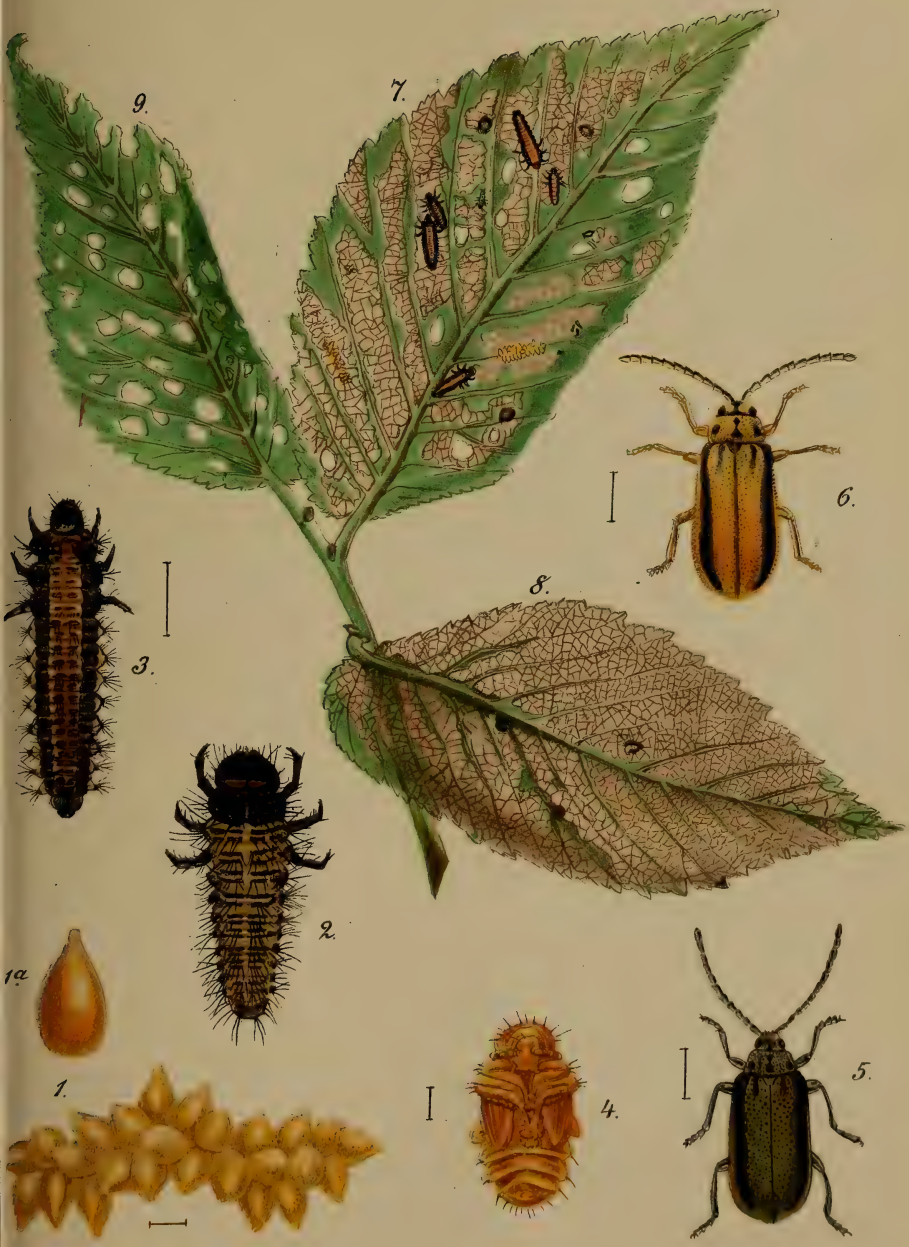
2 Work of elm leaf beetles, showing characteristic holes (original)

PLATE 8

Gossyparia ulmi Geoff.

1 Females, slightly enlarged

2 Cocoons of males, three times natural size



H. Joutel, 1900

ELM LEAF BEETLE

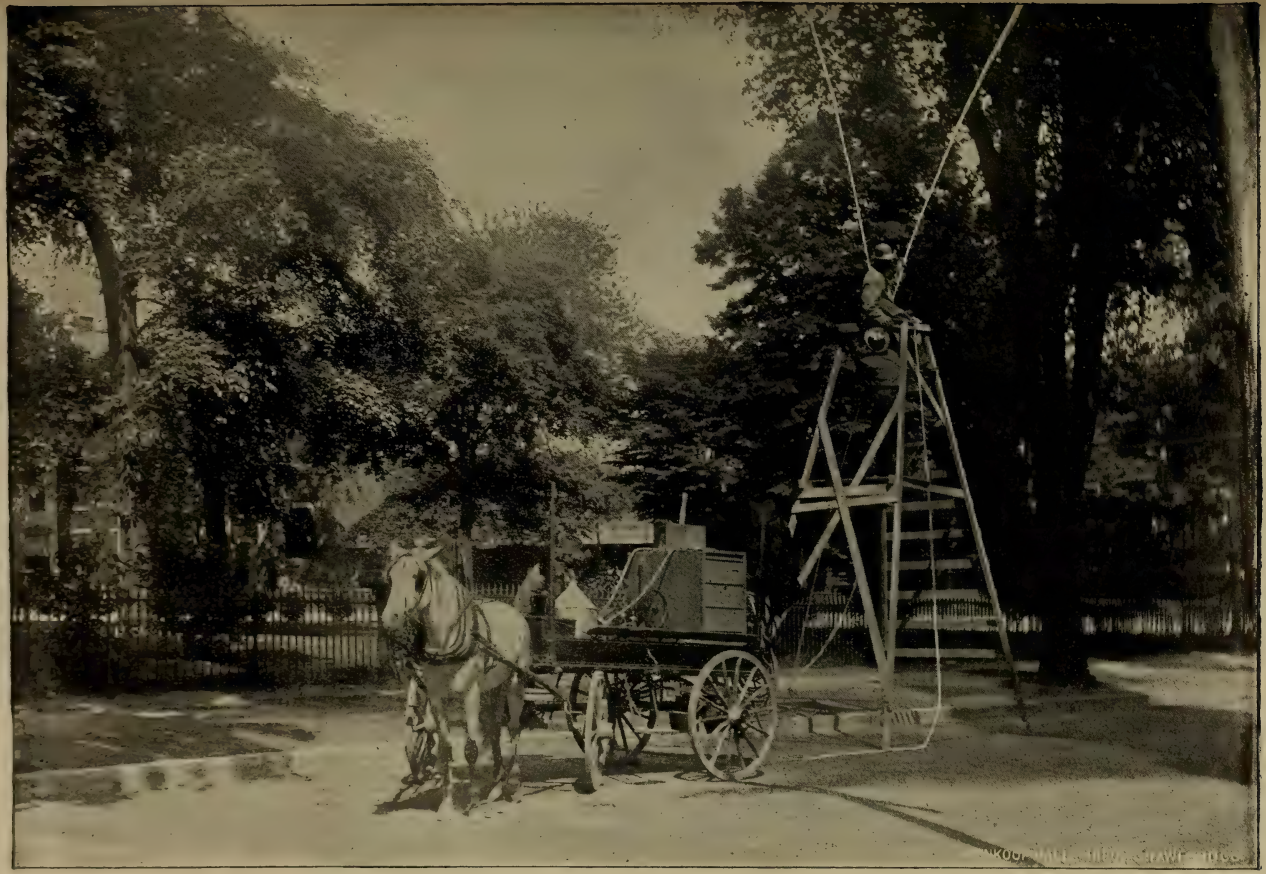
James B. Lyon, State Printer

(Reprint from 5th report of commissioners of fisheries, game and forests.)

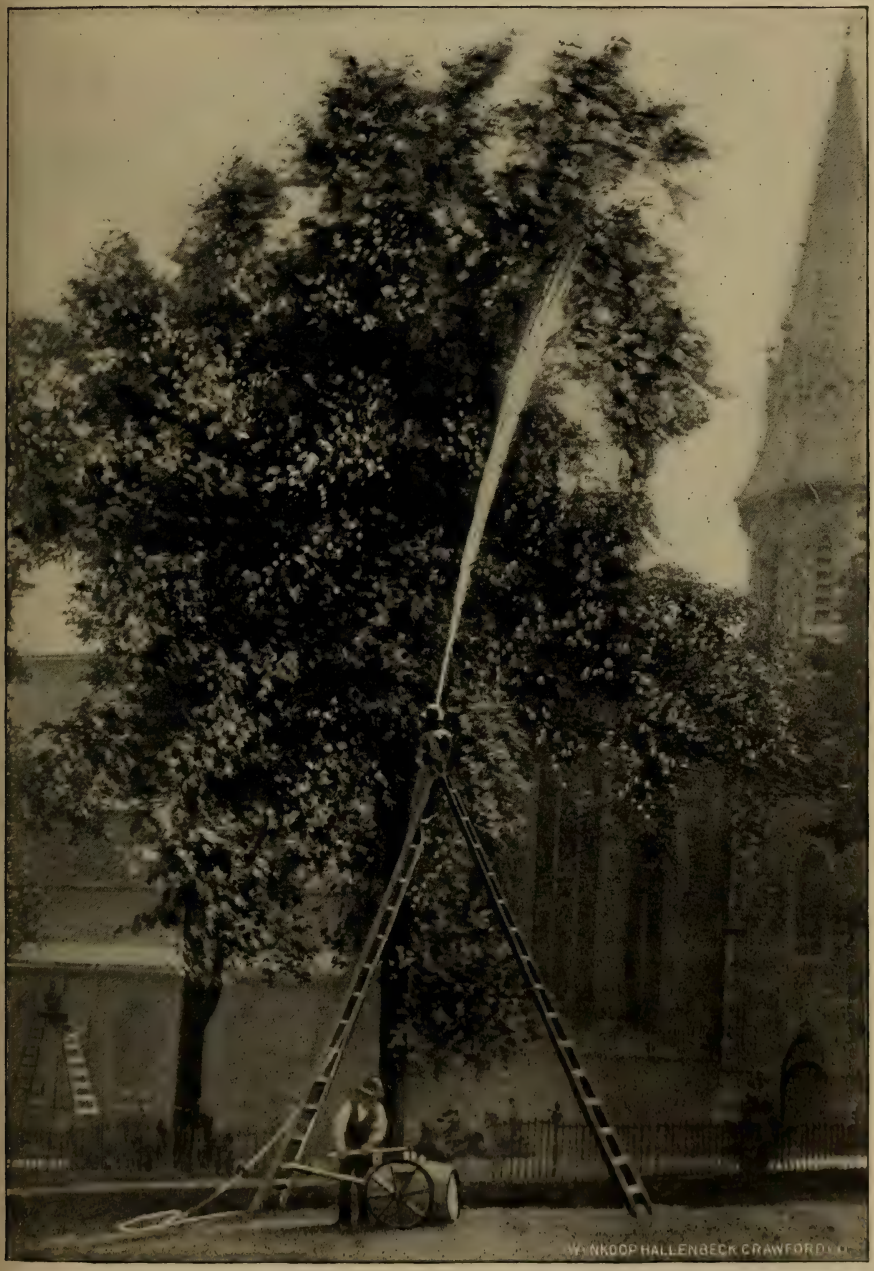
Upper austral life zone in New York state, which is the area likely to become infested by the elm leaf beetle (After Lintner)

Work of elm leaf beetle on Elm street, Albany Photo 15 June 1898

Work of elm leaf beetle on Jacob street, Troy Photo 15 June 1898



Power spraying outfit in operation Photo 15 June 1898



Hand spraying outfit in operation Photo 15 June 1898

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Elm leaf beetle work.

2

1

Elm bark louse

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New York State Museum

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